THE EFFECTIVENESS OF T-6A INSTRUMENT FLYING TRAINING AS COMPARED TO T-37B TRAINING

by

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This Graduate Research Project was prepared under the direction of the candidate's Research Committee Member Matthew W. Perkins, Adjunct Professor, Extended Campus, and the candidate's Research Committee Chair, Dr. Michael A. Van Doren, Adjunct Professor, Extended Campus, and has been approved by the Project Review Committee. It was submitted to the Extended Campus in partial fulfillment of the requirements for the degree of Master of Aeronautical Science.

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ABSTRACT

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The purpose of this graduate research project was to examine the effectiveness of instrument flying training conducted in the T-6A compared to training in the T-37B to prepare student pilots for follow-on advanced trainer aircraft. The United States Air Force’s newest primary trainer, the T-6A, has several technological advances over its predecessor, the T-37B. A general opinion exists among U. S. Air Force primary flying instructors and senior leadership that the T-6A is better equipped than the T-37B to prepare students for follow-on glass cockpits, and significant advances in cockpit technology suggest it might provide a better platform for instrument training. Data was collected for student grades achieved on T-38A advanced trainer instrument maneuvers at Laughlin Air Force Base, and was analyzed to compare performance of 39 prior T-6A students with 35 prior T-37B students. The overall mean of T-6A students’ grades surpassed the T-37A students, and the T-6A students had higher average scores on a majority of maneuvers. However, there was no statistically significant difference between the groups. Among other conclusions, this suggests that digital glass cockpits do not necessarily offer better fundamental instrument training than older, analog designs.

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CHAPTER I

INTRODUCTION

Background of the Problem

United States Air Force (USAF) student pilots progress through several stages of training before becoming mission qualified in an aircraft. Primary flying training in Specialized Undergraduate Pilot Training (SUPT) provides a solid foundation for advanced SUPT flying training and follow-on training. Instrument flying is one fundamental skill taught in primary training. Instrument proficiency typically factors into flying mishap prevention and common risk assessments. This is due to the simple fact that good instrument skills are vital to flying safety, as illustrated by statistics of numerous weather-related aircraft accidents (FAA, n.d.). It is, therefore, essential for USAF pilot training to provide the best foundation of instrument training available. Since the quality of training is partially a product of the cockpit environment, a superlative instrument-training platform is fundamental to molding new pilots.

The Department of Defense 1989 Trainer Aircraft Masterplan (DoD 1989 TAM) called for replacement of the aging T-37B primary trainer aircraft (DoD, 1989). It also advocated replacing the T-37B before the T-38A bomber-fighter trainer so that the T-38A replacement could be designed with knowledge of capabilities of the new primary trainer (DoD, 1989). The DoD 1989 TAM was based on an assumption that as much training as possible should be accomplished at the lowest possible level and should complement later training (DoD, 1989). The T-37B replacement took the form of the Joint Primary Aircraft

Trainer System, better known as the T-6A Texan II (AETC, 2000), which is equipped with a glass cockpit and minimal automation.

Great strides in the International Civil Aviation Organization's plan for Communications, Navigation, Surveillance / Air Traffic Management (CNS/ATM) have ushered in a wealth of new technology in the cockpit (Galotti, 1997), including an influx of digital displays and automation. The probability is great that today's new military pilots will fly in an automated glass cockpit at some point in their careers, if not immediately after SUPT. Glass cockpits, however, can present challenges to most pilots who are new to them (MacGregor, 2000). *Glass cockpit syndrome* has been blamed for serious accidents, including the unintentional shoot-down of an Iranian airliner by the U.S.S. Vincennes (Squires, 1988).

Researcher's Work Setting and Role

The researcher was recently a USAF instructor pilot in a T-6A SUPT squadron at Moody Air Force Base (AFB), Georgia. He has over six years experience instructing primary flying training in Air Education and Training Command (AETC). Previous positions held in AETC flying training squadrons include that of student Flight Commander, squadron Chief of Training, and squadron Chief of Safety. He has logged over 1,900 hours in the T-37B and T-6A, and over 3,600 hours total flying time, with prior experience flying the USAF C-130E, C-130H, and T-38A.

Statement of the Problem

The T-6A has been used for three years as a USAF primary trainer since it was first introduced at Moody AFB, Georgia in 2001. The DoD 1989 TAM called for SUPT to provide the best training possible for follow-on training, and for T-6A capabilities to be assessed before acquiring a T-38A bomber-fighter training system (BFTS) replacement. Furthermore, in the interest of safety, the USAF should continue to produce the best instrument-trained pilots possible. The researcher has witnessed a consensus in the SUPT field that the T-6A is a better trainer than the T-37B to prepare students for SUPT Phase III. There is also a belief that a glass cockpit primary trainer provides better preparation for automated, glass cockpit advanced trainers.

If the T-6A does not produce better instrument-trained pilots than the T-37B, then the belief that a glass cockpit primary trainer is better than a non-glass cockpit primary trainer may be a false assumption. Furthermore, if the T-6A produces worse trained instrument pilots than the T-37B, AETC should examine the T-6A training program to determine what adjustments need to be made to improve training effectiveness. Finally, assessment of the T-6A as an effective instrument trainer may provide additional insight and data for trainer cockpit design and for fielding a modification or replacement of the T-38A.

Definition of Terms

AETC - Air Education and Training Command; the USAF major command responsible for recruiting, educating, and training personnel. All USAF SUPT occurs within AETC.

glass cockpit - an aircraft cockpit or flight deck equipped with modern digital displays for flight instrumentation, usually in the form of cathode ray tubes (CRTs), or thin-film transistor (TFT) active matrix liquid crystal displays (AMLCDs) (Sutton, 1998).

JPATS - Joint Primary Aircraft Training System; an entire training system, including the T-6A aircraft, simulator training devices, academic training system, and computerized management system (AETC, 2000).

JPPT - Joint Primary Pilot Training; primary pilot training conducted in the T-6A trainer aircraft by both the U.S. Air Force and U.S. Navy, during which students learn basic, fundamental flying skills (see Specialized Undergraduate Pilot Training, below). JPPT uses common training systems for both services, including aircraft and syllabus.

JSUPT - Joint Specialized Undergraduate Pilot Training; an SUPT program conducted jointly, with U.S. Air Force, U.S. Marine Corps, and U.S. Navy instructors and students. JSUPT and SUPT use the same AETC syllabus for USAF T-6A training (see SUPT).

SUPT - Specialized Undergraduate Pilot Training; a specialized flying training program, tailored to better meet the demands of the gaining operational major commands. SUPT consists of three phases: Phase I is pre-flight ground training; Phase II is primary pilot training, conducted in the T-37B or T-6A; Phase III is advanced undergraduate pilot training, conducted in the Air Force T-1A or T-38A/C, Navy T-44, or Army UH-1 (DoD, 1989).

UPT - Undergraduate Pilot Training; the predecessor to SUPT. UPT was a generalized training program in which all students flew the T-38A in Phase III. In the UPT program, student training was only minimally tailored towards the gaining operational major command requirements during the approximate last month of flying the T-38A (DoD, 1989).

Limitations and Assumptions

This study focused on a limited sample size of students at one of four Air Force pilot training bases. Because the T-6A had been flown in SUPT at Laughlin AFB for a little over a year before data was collected for this study, limited student training data was available for analysis. The test sample size was further limited due to T-1A data being unavailable. The researcher sought performance data for a minimum of 120 SUPT students who attended training at Laughlin AFB, Texas. However, data was only available for 74 T-38A students to be included in this study.

Weather phenomena, traffic patterns, local instrument approaches, and other training conditions differ among SUPT bases and may bias student proficiency in specific skills. To minimize such variables affecting student experience and proficiency and adding bias to the data, the researcher sought to compare students who conducted training at the same airfield. An ideal setting for the comparison would be one in which students progressed through SUPT training at the same base during the same time, with the main variable being the Phase II aircraft trainer system (i.e., T-37B versus T-6A). At the time of data collection, Laughlin AFB was the only base where both the T-37B and T-6A were simultaneously used to teach SUPT Phase II, so the researcher chose to analyze data from student training only at Laughlin. Limiting data to one SUPT base decreases the available sample size and increases the risk of error if the selected Laughlin students are not representative of the entire SUPT student population. However, in the researcher’s opinion, the benefit gained by reducing variables outweighed limiting data in this manner. The researcher assumes the test sample of Laughlin students is representative of the entire population of SUPT students.

CHAPTER II

REVIEW OF RELEVANT LITERATURE AND RESEARCH

Overview of Specialized Undergraduate Pilot Training

United States Air Force (USAF) student pilots progress through several flying training stages before becoming mission qualified in an operational aircraft. Students must first attend USAF-administered Introductory Flight Training (IFT) at the US Air Force Academy or a school meeting Federal Aviation Regulation Part 61 or Part 141 requirements (Introductory Flight Training, 2003). Following IFT, some Air Force students attend Euro-NATO Joint Jet Pilot Training (ENJJPT) or US Navy primary flying training, but most proceed to Specialized Undergraduate Pilot Training (SUPT) or Joint SUPT (JSUPT). JSUPT refers to a joint SUPT program conducted at Vance Air Force Base, Oklahoma, employing instructors and students from the U.S. Air Force, U.S. Marine Corps, and U.S. Navy. JSUPT and SUPT use the same training syllabus and are synonymous for the purposes of this study.

SUPT is the first formal military flying training program students attend, lasting approximately one year. Students who successfully complete SUPT earn an Air Force pilot rating. For the majority of students, SUPT represents their first exposure to flying high performance turbine engine-powered aircraft. SUPT is comprised of three phases. Phase I is approximately one month of pre-flight academics and ground training. Phase II is primary flying training, conducted in the T-37B or T-6A, and lasts approximately four and one-half months (United States Air Force, 2003b). At the end of Phase II, Air Force students are rank-ordered based on their performance, and assigned to one of four SUPT Phase III tracks. Phase III is advanced flying training, conducted in the Air Force T-1A or T-38A, the Navy T-44, or the Army UH-1. Phase III training in the T-1A and T-38A last approximately six months (United States Air Force, 2003a, 2003c).

The Joint Primary Aircraft Training System

The aging T-37B "Tweet" aircraft has been used for primary flying training for over half a century. According to the DoD 1989 TAM, it is the oldest trainer in the U.S. military inventory, with "increasingly marginal performance, dated environmental provisions, and questionable supportability" (DoD, 1989).

In 2001, the USAF began replacing T-37B aircraft with T-6A Texan II aircraft to instruct student pilots in primary flying training. The T-6A aircraft was acquired as part of a larger training system known as the Joint Primary Aircraft Training System (JPATS), to be used for USAF and US Navy pilot and navigator training (AETC, 2000). JPATS encompasses a whole training system that includes the T-6A aircraft, simulator training devices, academic training systems, and a computerized management system. According to the JPATS System Training Plan Final Report (D.P. Associates, Inc., 1995), the purpose of JPATS for pilot training is to train entry-level student pilots to a level of proficiency where they can transition into an advanced training track.

Maximizing Training at the Earliest Stages

According to the DoD 1989 TAM, Air Education and Training Command (AETC) should accomplish as much training as possible in SUPT, and that training should dovetail with follow-on training (DoD, 1989). The DoD 1989 TAM states that SUPT is just the initial part of several phases in training USAF pilots, and a considerable amount of conversion and follow-on training is required after

SUPT before a pilot is qualified in the mission of their assigned aircraft. Because of this, it is important that SUPT programs interface with and complement flying training programs of the gaining major operational commands (DoD, 1989).

It is more cost efficient and a better use of resources to complete as much training as possible in the least costly aircraft. If one considers the costs of fuel, personnel, equipment, facilities, maintenance, and other support, it is much more cost efficient to conduct training in SUPT because of the higher cost of training in follow-on operational aircraft such as the F-22, C-17, B-2, or KC-10 (DoD, 1989). Conducting as much training as possible at the earliest stages of training also frees up operational aircraft for more operational mission requirements (DoD, 1989).

SUPT training syllabi are living documents, subject to continuous review and modification. Changes in Air Force operational needs, training philosophy, and aircraft capabilities are some of the factors that drive changes in a syllabus. In the case of the T-6A, a joint Navy-Air Force syllabus was developed due to the joint nature of the JPATS program. Combining training philosophies and requirements from the two services into a single document has required careful coordination. To a great degree, the JPATS syllabus was initially based on experience with T-37B and T-34C primary trainers that the T-6A would replace. As SUPT instructors gained experience with students in the T-6A, differences in aircraft capabilities have driven some of the subsequent syllabus changes.

When considering the DoD 1989 TAM, one can conclude it is important that the T-6A syllabus capitalize on T-6A capabilities to instruct as many flying skills as possible that complement and interface with advanced SUPT training and follow-on flying training. If the T-6A syllabus proves less effective than the T-37B syllabus, it would warrant examination to determine what adjustments would maximize the effectiveness of primary training.

Primary Training - a Foundation for Instrument Flying Skills

In primary training, students are introduced to maneuvers such as aircraft takeoffs and landings, basic handling techniques, recovery from unsafe flight situations, aerobatics, instrument flying, cross-country navigation, night flying, and close formation flying. Flying skills and techniques learned in primary training form the foundation for Phase III and follow-on flying training. Experienced USAF pilots recounting aircraft malfunctions or in-flight emergencies often describe how they respond to high task load situations by reverting to fundamental skills learned in primary flying training. It is therefore important that primary training be as effective as possible in forming a solid foundation of basic flying skills.

A study by the Federal Aviation Administration (FAA) revealed that weather was a contributing cause or factor in 21.1 percent of all aircraft accidents occurring between 1991 and 2001 (FAA, n.d.). In that study, the FAA’s Office of System Safety analyzed accidents recorded in the US National Transportation Safety Board’s (NTSB) accident and incident database to find accidents caused by or contributed to by weather. Although the annual number of accidents related to weather declined from 1991 to 2001, the proportionate share of total accidents that were weather-related has remained roughly the same (FAA, n.d.).

Another study of aircraft accidents in Alaska between 1992 and 2001 showed that accidents occurring during instrument meteorological conditions (IMC) had a fatality rate more than four times higher than accidents occurring during visual meteorological conditions (VMC) (i.e., thirty-nine percent IMC vs. eight percent VMC) (FAA, 2003).

Those studies suggest that a good foundation in instrument flying skills may be a key factor in reducing aircraft accident fatality rates. In this researcher's own flying and instructional experience, a pilot's task load when resolving unexpected problems increases significantly if the problems occur during manual flight in IMC. Since task load can be reduced by improving proficiency and skill level, it follows that a good foundation in instrument flying skills learned in primary flying training can lead to better proficiency, reducing the risk factor for a fatal accident.

Shortcomings of the T-37B

According to a 2000 USAF Operational Requirements Document (ORD) for the Joint Primary Aircraft Training System (JPATS), "the Navy's T-34C and the Air Force's T-37B… are operationally outdated and increasingly limited in training the skills required in follow-on aircraft" (AETC, 2000, p. i). The 2000 ORD also states that one of four shortcomings of the T-37B and T-34C systems forming the basis of need for the JPATS are that T-37B and T-34C cockpits are equipped with outdated analog systems "not representative of any current aircraft cockpits" (AETC, 2000, p. 2). The 2000 ORD specifies a requirement that the JPATS be equipped with selectable electronic attitude director indicator (EADI) and electronic horizontal situation indicator (EHSI), with a desire to have all digital IFR certified instruments, except for backups (AETC, 2000, pp. 4-5).

The DoD 1989 TAM calls for a T-37B replacement aircraft that would be more capable of teaching skills necessary in modern technology aircraft (DoD, 1989). Furthermore, the DoD 1989 TAM calls for the JPATS system to be operationally fielded before a replacement for the T-38A, the bomber-fighter trainer (DoD, 1989). The DoD 1989 TAM specified that a T-38A replacement would have some of its requirements based on capabilities of the JPATS aircraft (DoD, 1989). It is, therefore, important that an accurate assessment be made of the T-6A training capabilities before completion of a T-38A modification or replacement. This study may provide valuable insight for such an assessment by examining a specific aspect of the T-6A: effectiveness as an instrument trainer.

A Trend towards Advanced Technology Cockpits

The question is not whether military pilots will have experience with digital glass cockpits and automation, but rather when they will gain the experience. If they continue in a flying career, they will inevitably confront the new technology. The International Civil Aviation Organization’s plan for Communications, Navigation, Surveillance / Air Traffic Management (CNS/ATM), which evolved from the Future Air Navigation System (FANS) concept, has driven significant design changes in the cockpits of modern aircraft (Galotti, 1997). Technological improvements in displays, automated systems, and avionics are being applied to commercial airliners, military aircraft, and even general aviation aircraft as costs decrease for production and equipage. Even if an aircraft acquisition or modernization program does not call for more costly systems such as a Traffic Alert and Collision Avoidance System (TCAS), a Flight Management System (FMS), or an autopilot, there are benefits gained by installing digital displays rather than analog instruments as primary flight displays.

Digital displays are capable of more flexibility, allowing a pilot to select alternative displays of information. This allows redundancy, providing a safety benefit. It also allows space and weight savings, leading to lighter aircraft designs and improved cost efficiency (Siuru & Busick, 1994, pp. 87-88). Active matrix liquid crystal displays (AMLCDs), the same technology found in modern computer flat panel displays (Sutton, 1998), are an attractive design component for modern cockpits. AMLCDs are more reliable, cheaper, and require less power than their cathode ray tube (CRT) predecessors, while displaying more flexible, sharper images (Sutton, 1998). The T-6A is equipped with several AMLCDs for primary flight and engine instruments (Department of Defense, 2000).

R. G. Green, Muir, James, Gradwell, and R.L. Green identified standardization as a critical ergonomic element of cockpit display and control design (1996, p. 115). In *Human factors for pilots*, Green et al. explain that a “T” design, as depicted in Figure 1, below, is the usual standard for conventional basic flying instruments (1996, p. 115). They point out that a non-standard flying instrument arrangement can create confusion and negative transfer for the pilot (Smith et al., 1996, p. 115).

The T-37B primary flight instrument layout does not follow the widely used “T” design (see figure 2). The Instrument panel design of the T-6A primary flight instruments is in a typical “T” configuration (see figure 3). The length of time required for crosscheck adaptation by a student transitioning from a T-37B to an

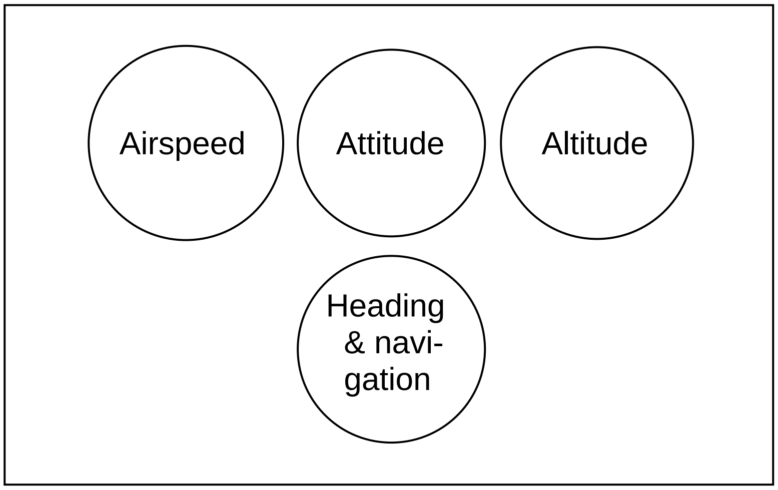

Figure 1. Typical “T” Arrangement of Primary Flight Instruments.

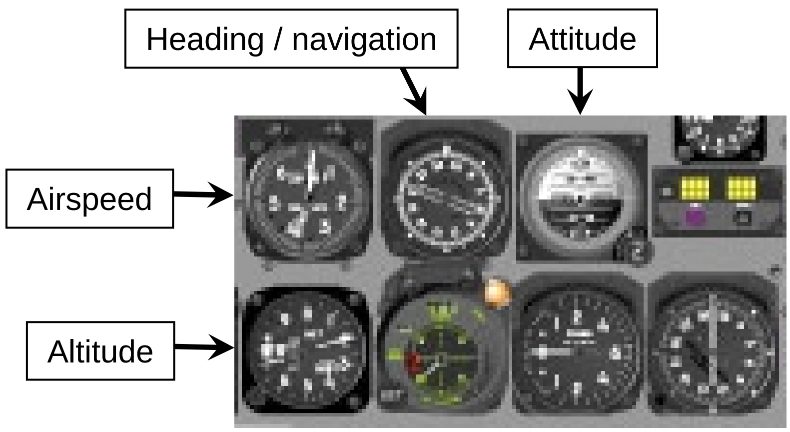

Figure 2. T-37B Primary Flight Instruments. *Note.* From *U.S. Air Force T-37B cockpit configuration trainer,* by PaperTrainer.com (n.d., Eads, TN) Reprinted with permission.

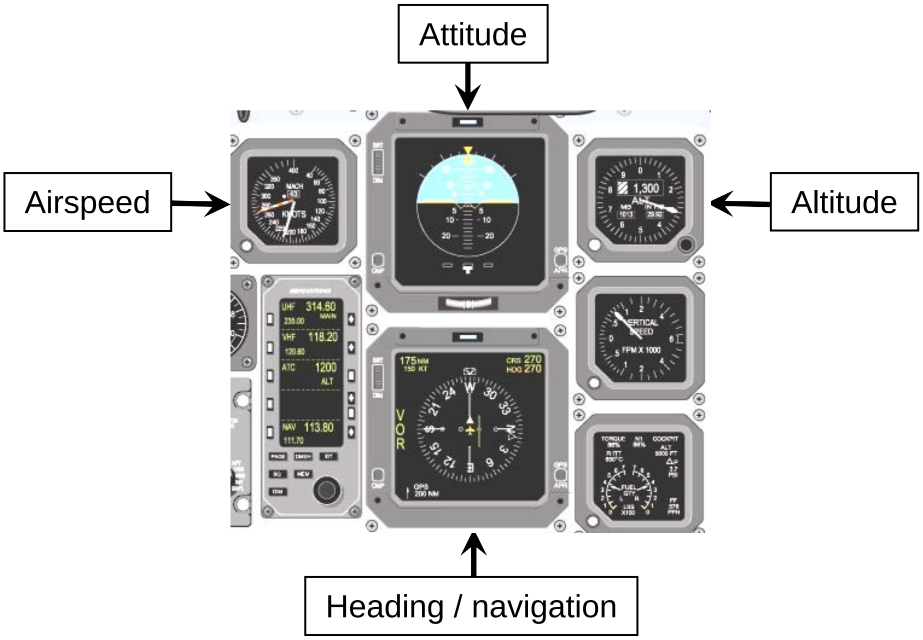

Figure 3. T-6A Primary Flight Instruments. *Note.* From Raytheon Aircraft Company (2002, Wichita, KS) Reprinted with permission.

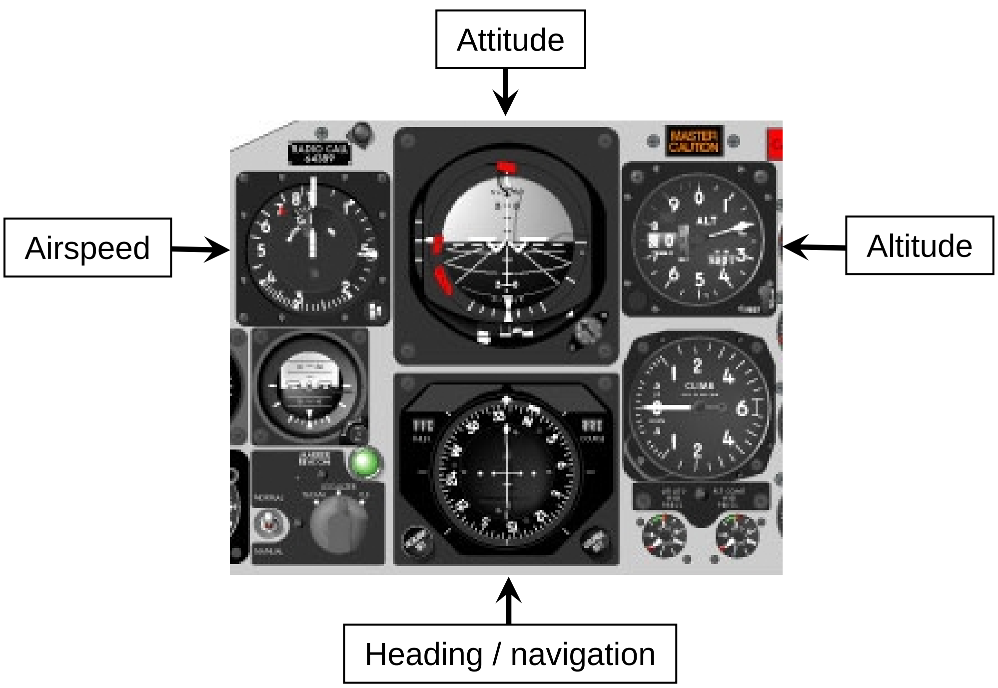

Figure 4. T-38A Primary Flight Instruments. *Note.* From *U.S. Air Force Northrop T-38 cockpit configuration trainer,* by PaperTrainer.com (2004, Eads, TN) Reprinted with permission.

Figure 5. T-1A Primary Flight Instruments. *Note.* From Raytheon Aircraft Company (n.d., Wichita, KS) Reprinted with permission.

aircraft with a standard instrument layout such as the T-38A, shown in Figure 4, or the T-1A, shown in Figure 5, above, and amount of degraded performance score because of the difficulty, is unknown. However, the difference likely accounts for some degraded performance on the part of a prior T-37B student.

Managing Glass Cockpit Information

As new student pilots learn to operate digital equipment found in modern glass cockpits, they must learn to cope with unexpected errors in automated and computerized systems. For example, data input mistakes, software peculiarities, or uncorrected system design errors can cause automated equipment to operate in unexpected ways. A student’s ability to correct such errors will depend in part on how well the student digests displayed information, understands the underlying system, and prioritizes tasks. USAF primary flying training instructors repeatedly emphasize to students that flying the aircraft (i.e., maintaining positive control of attitude, altitude, airspeed, power setting, and other desired flight parameters) must take priority over other, less-essential, mission tasks in the cockpit. MacGregor (2000) draws a parallel between teaching a student pilot to prioritize flying the aircraft, and teaching a student or new instructor to transition to a glass cockpit. He explains that a typical response to automation or computer errors is for the new pilot to "check, recheck and 'reprogram' the computers" (MacGregor, 2000, p. 25), rather than take over and exercise manual control of the aircraft or manual calculations.

Squires explains how high technology and information overload contributed to the unintentional shoot-down of an Iranian commercial airliner by the crew of the U.S.S. Vincennes (1988). According to Squires, aircraft and ship crewmembers operating high-technology equipment are susceptible to what psychologists call glass cockpit syndrome -- a situation where a flood of technical information, faulty crew communication, and external stress combine to cause major errors in judgment (1988).

Although the T-6A employs modern technology in its design, advanced trainers in SUPT Phase III and follow-on aircraft are equipped with more automation and more complex displays than the T-6A. For instance, the T-6A lacks such systems as color weather radar display, TCAS, an FMS, or an autopilot -- all of which are found in the T-1A. Nor does the T-6A have a heads-up display, which is currently being installed in the T-38C. To a degree, pilots will require time to adjust to any aircraft new to them, regardless of experience with advanced technology. It would be valuable to know whether exposure to glass cockpit technology in primary trainers affects a student’s ability to adjust to the modern technology of advanced trainer cockpits.

Statement of Hypothesis

A question remains as to whether pilots with little or no experience in digital cockpits (e.g., T-37B primary students) will require more time to adjust to complex automated cockpits, and subsequently lag in performance throughout training, when compared to pilots who have digital cockpit experience (e.g., T-6A primary students). A finding that student performance difference is negligible might suggest that it is false to assume that an advanced digital cockpit in a primary trainer provides a better foundation for more complex automated cockpits in advanced trainers and follow-on aircraft.

The hypothesis is that USAF SUPT Phase II T-6A students do not perform the same as T-37B students when adapting to SUPT Phase III instrument flying maneuvers in the T-1A and T-38A. The testable hypothesis is that there is a statistically significant difference, at a 95% (α=.05) level of significance, in SUPT Phase III instrument maneuver performance between students who flew the T-6A in SUPT Phase II and students who flew the T-37B in SUPT Phase II. The null hypothesis is that there is no statistically significant difference, at a 95% (α=.05) level of significance, in SUPT Phase III instrument maneuver performance between students who flew the T-6A in SUPT Phase II and students who flew the T-37B in SUPT Phase II.

CHAPTER III

RESEARCH METHODOLOGY

Research Design

Historical student pilot grade data maintained by AETC was requested for statistical analysis of SUPT Phase III instrument maneuver performance. A comparison was made between Phase III performance of students who flew the T-37B in Phase II, and Phase III performance of those who flew the T-6A in Phase II. A *t*-test was performed to determine if a statistically significant difference exists (Gay & Airasian, 2003) between former T-37B students and former T-6A students.

Two separate *t*-tests of Phase III data were planned to compare former T-37B students with former T-6A students - one test of T-38A student data and one test of T-1A student data. Separate tests were planned because T-38A and T-1A training syllabi differ, so different instrument maneuvers would be examined for each of those aircraft. The T-38A group and T-1A group would each be tested to determine if a statistically significant difference was found. If a significant difference existed, the data was to be analyzed further to determine which group favored better performance in Phase III. However, T-1A data was not available for the study, so only T-38A student data was tested with a single *t*-test.

Survey Population

The population sample consisted of USAF student pilots who flew the T-37B or T-6A primary trainers and attended SUPT Phase III at Laughlin AFB, Texas since January 2003, when the T-6A began service there as a primary trainer. Analysis was conducted on select instrument maneuvers in the T-38A Basic and

Instrument training categories. Students included in the assessment were those who had completed these categories of training by the time data was requested.

Sources of Data

Data was extracted from databases maintained by Headquarters AETC. T-38A data for the subject time period is maintained in the Time Related Instruction Management (TRIM) database, and the Training Integration Management System (TIMS) database. These databases provide historical archives of all grades achieved by all students in the SUPT T-38A program. The databases are not interconnected with each other, nor are the data stored in similar formats.

The Data Gathering Device

Initial data collection was done by instructor inputs into the TRIM and TIMS systems. Each training syllabus groups aircraft and simulator sorties into training units according to similarity of training objectives. In each aircraft and simulator unit of training, specific maneuvers must be accomplished to a minimum level of proficiency before a student is allowed to progress to subsequent training units (United States Air Force, 2003a, 2003b, 2003c). TRIM and TIMS are used to record the level of proficiency assessed by the instructor for each maneuver attempted by the student on a sortie.

TRIM inputs are made by means of instructor-completed paper grade sheets. Provisions exist to input grades into TRIM through a graphical user interface (GUI) on a desktop computer. However, instructors at most SUPT bases have historically used pencil-marked paper grade sheets designed for batch input on a scanning machine that interfaces with the TRIM system. In the newer TIMS, however, instructors input grades exclusively through a GUI running on a computer workstation. Regardless of the input method or storage system, instructors input student grades into the system by the end of the day.

Data collection for this study was accomplished by mining database records on file. Database managers at Headquarters AETC and Moody AFB, GA provided specific data requested by the researcher. They queried it from the databases, exported it to usable file formats, and sent it to the researcher via e-mail. One file of TRIM data was provided as a Microsoft Excel file, and one file of TIMS data was provided as a Microsoft Access file.

Instrument Reliability and Validity

Data reliability and validity are expected to be quite high, but cannot be measured quantitatively. Reliability assessment is based on the researcher's past experience with SUPT student grade books. Maneuver scores are recorded immediately following each sortie, and input into the computer system within a day, or immediately in the case of desktop computer grading. On a daily basis, the student is responsible for maintaining a written copy of grades an IP assessed, and verifying written grades against computer-generated grade products printed later in the week. On a weekly basis, the student performs a thorough grade book check for errors, as does at least one instructor. A second, and possibly third, instructor also checks the grade book for accuracy on a biweekly basis. Finally, the grade book undergoes a thorough scrub for errors at the end of the training phase, before the student's records are officially closed by the school registrar to lock further changes to the data.

Any lack of reliability in this measurement most likely occurred in the area of rater agreement. Students receive a grade of Unsatisfactory, Fair, Good, or Excellent on maneuvers they accomplish. The syllabus for each training program explains specifically how to assess performance when assigning a grade, and specifies detailed training standards against which to grade students on any given maneuver (United States Air Force, 2003a, 2003b, 2003c). Nonetheless, maneuver grade assessment by an instructor most often involves subjectivity. This is not due to a weakness in the system, but because no amount of standards and instructions can take the multitude of events and decisions that occur in the course of a sortie and distill them into 44 individual letter grades that make up a grade sheet. Over time, however, issues of rater agreement would tend to be eliminated as each instructor flies with several different students and shares knowledge and grading techniques amongst fellow instructors.

Validity of the data for this research is very good (a subjective assessment, as stated before). The purpose of this study was to determine whether instrument training in Phase II was effective preparation for later instrument training. Since the Phase III grade data is a direct indication of performance and a key measurement used by the USAF to rank order students' graduation standing, it was the best measurement available of how students actually performed in flying training in the USAF SUPT environment.

Treatment of Data and Procedures

Due to the T-38A grade recording system changing from TRIM to TIMS in August 2003, the data for the time period of this study was stored in both TRIM and TIMS databases (C. Michaels, HQ AETC/DOZQ, personal communication, March 2004). The manner of data retrieval resulted in two separate files being provided for analysis: a Microsoft Excel spreadsheet and a Microsoft Access table. The two files stored records with different array dimensions, different fields, different field formats, and several other differences that did not allow a simple merge. The researcher imported the excel data array into a new access table, used several queries and conversions to rearrange the two record sets into common structures, and then merged both sets of data into a single Access table containing over 93,000 records. Microsoft Excel was then used to create pivot tables and charts linked to the single Access data table, and to perform calculations.

Ground training events (i.e., non-flying and non-simulator) were eliminated from the data. Maneuvers that do not rely on instrument flying skills were filtered out of the data using Access queries. A list of the instrument maneuvers that were included in the analysis is shown in Table 4 in Appendix B, and a list of sorties included is shown in Table 5 in Appendix B. For reference, Figures 7 and 8 in Appendix C show all maneuvers and sorties in the Basic and Instrument categories of the 2003 T-38A SUPT syllabus.

The researcher converted letter grades in the data to numbers based on the Maneuver Item File proficiency grade scale specified in all SUPT syllabi. Using that scale, proficiency letter grades equate to the numbers shown in Table 1, below. However, the researcher elected to eliminate all grades of *No Grade* (NG) from the calculations. Rationale was that these NG grades equate to a score of 1 out of 5 if the proficiency grade scale is followed, and this would skew some score averages without respect to the students' actual performance. A grade of NG means the instructor demonstrated a maneuver to a student and the student did not actually perform the maneuver. Beyond syllabus requirements that direct specific maneuver demonstrations, all students do not receive the same exposure to demonstrated maneuvers, and therefore, do not receive the same number of NG grades. A student who had more demonstrated maneuvers scored and included in his or her average would have a lower overall average than another student with equal scores besides the NG grades would. Therefore, including NG grades in the calculations would erroneously lower some students' averages.

Table 1

Proficiency Grades (Letter - Number Equivalents)

Proficiency grade	Letter grade	MIF level	Maneuver proficiency
Excellent	E	5	Correct, efficient, skillful
Good	G	4	Satisfactory
Fair	F	3	Safe, but limited proficiency
Unsatisfactory	U	2	Unsafe or unable
No Grade	NG	1	Demonstrated if dual; unobserved if solo

Proficiency maneuver grades, with letter and number equivalents. *Note.* From *T 38A Specialized Undergraduate Pilot Training, with changes 1 and 2* (p. 9), by the United States Air Force, 2003, San Antonio, TX: Air Education and Training Command.

After making the adjustments explained above, the researcher used Access to calculate an average score for each student for all the selected instrument maneuvers on all the sorties. The student average scores are shown in Table 6 in Appendix B. Statistical tests and chart calculations were then performed in

Excel files linked to the Access data. The T-38A data was tested for a difference of variances (*F*-test) and then a difference of means (*t*-test) between two groups of students: those who flew the T-37B in Phase II and those who flew the T-6A in Phase II.

Before performing a *t*-test on the data to find significance of the difference of the means, it was first necessary to perform an *F*-test to determine whether data variances were equal or unequal (Burati, Weed, Hughes, & Hill, 2003, p. F-2). The results of the *F*-test would dictate whether to perform a *t*-test for independent data with equal variances or a *t*-test for independent data with unequal variances. Some statistics software programs automatically perform an *F*-test, also referred to as Levene’s test, as part of a *t*-test calculation (Gay & Airasian, 2003, pp. 462-463), but the Microsoft Excel *t*-test data analysis tool does not do this.

For the *F*-test, the null hypothesis was that there is no statistically significant difference in variances (i.e., variances are equal) between the average scores of former T-37B students and the average scores of former T-6A students, at a 95% level of significance ($\alpha = .05$). If the null hypothesis were rejected, unequal variances would be assumed. If the null hypothesis were not rejected, equal variances would be assumed.

CHAPTER IV

RESULTS

Due to the amount of time required to complete SUPT Phase II and an estimate of time required for students to progress through the T-1A Transition category and T-38A Basic and Instrument categories, the researcher estimated the total survey population would be approximately 120 students. However, since T-1A data was not available, the total sample size was 74 T-38A students (35 former T-37B students and 39 former T-6A students).

Table 2, below, shows the results of an *F*-test performed using the Microsoft Excel data analysis add-in tool. Because the Excel *F*-test add-in tool only calculates a one-tailed *F*-test, α = .025 was used for a one-tailed test to get the effect of a two-tailed test for α = .05. In other words, the value of a one-tailed *F*crit calculated with α = .025 is the same as a two-tailed *F*crit with α = .05. Since *F* < *F*crit (i.e., 1.123 < 1.932), the null hypothesis of equal variances is not rejected, so variances are assumed to be equal. Alternatively, the one-tailed

Table 2

F-test Two-Sample for Variances

	T-37B Students	T-6A Students
Mean	3.864324759	3.924491237
Variance	0.031350406	0.027880236
Observations	35	39
df	34	38
F	1.124467021	
P(*F*<=*f*) one-tail	0.361131655	
F Critical one-tail	1.932214388	

Note. Calculated in Microsoft Excel 2002 SP3, with alpha = .025, and grade averages listed in Table 6 input as variable data.

P(*F*<=*f*) value of 0.361 multiplied by two yields a two-tailed *P*(*F*<=*f*) value of 0.722. Since the two-tailed *P*(*F*<=*f*) is greater than two-tailed *α* (i.e., 0.722 > .05), the null hypothesis of equal variances is not rejected and equal variances is assumed.

Therefore, a two-sample *t*-test assuming equal variances was the correct test to perform (Burati et al., 2003, p. F-2). Table 3, below, shows the results of a *t*-test performed using the Microsoft Excel data analysis add-in tool. The absolute value of two-tailed *t* is less than *t*crit (i.e., │-1.504│ = 1.504 < 1.993), so the null hypothesis is not rejected. The *t*-test therefore indicates no statistically significant difference exists between the means of the two groups, so the stated hypothesis of this study is not supported.

Table 3

t-test: Two-Sample Assuming Equal Variances

	T-37B Students	T-6A Students
Mean	3.864324759	3.924491237
Variance	0.031350406	0.027880236
Observations	35	39
Pooled Variance	0.029518927	
Hypothesized Mean Difference	0	
df	72	
t Stat	-1.504024023	
P(*T*<=*t*) one-tail	0.068474638	
t Critical one-tail	1.666294338	
P(*T*<=*t*) two-tail	0.136949276	
t Critical two-tail	1.99346232	

CHAPTER V

DISCUSSION

The overall T-6A student score mean of 3.924 in this study was higher than the overall T-37B student score mean of 3.864. Figure 6, below, shows a graph of the average score of the two test groups on each T-38A instrument maneuver included in the tests. A comparison of individual maneuvers shows that the group of T-6A students had a higher average score than the T-37B students in 40 out of 46 maneuvers. Although this study showed a real difference that favored the T-6A student group, it failed to support a statistically significant difference between the groups.

Based on the findings, it appears that the T-37B proved to be as good an instrument trainer as the T-6A. This suggests that employing a glass cockpit with minimal automation has negligible impact on the effectiveness of instrument training in a primary trainer. An alternative explanation might be that the T-6A in SUPT has not yet reached its potential as an instrument trainer. It is conceivable that the primary training culture in AETC, steeped in a half century of T-37B analog instructional techniques and standards, has not yet evolved enough to capitalize on techniques and methods that favor strengths of a digital cockpit. Whatever the reason, the results at least support that the T-6A is at least as good as its predecessor for instrument training.

In a 2003 study by Perkins, an analysis of mean sortie failure rates in SUPT Phase III showed that there was a statistically significant difference between former T-37B students and former T-6A students. This study had several

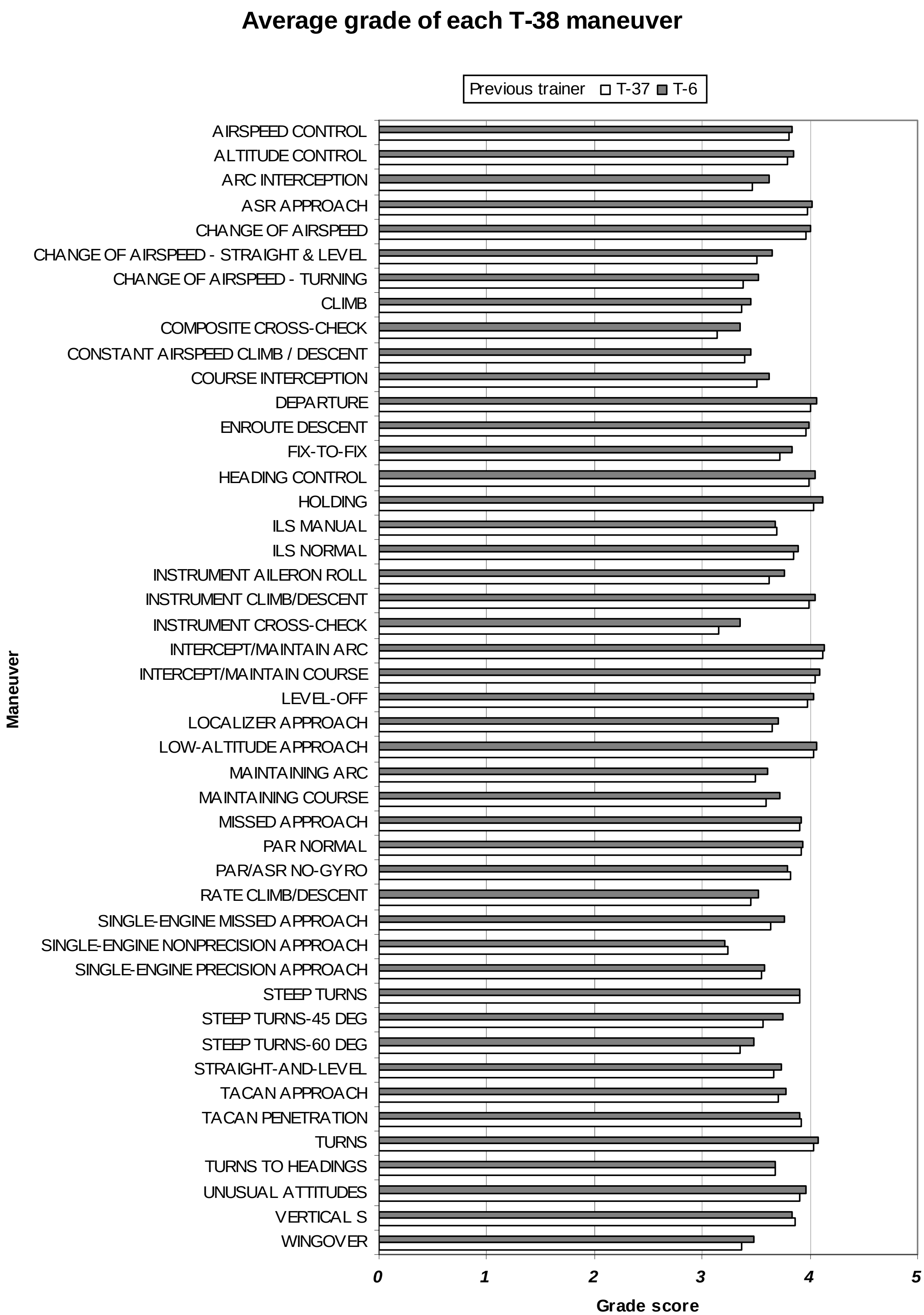

Figure 6. Average T-38A Instrument Maneuver Scores.

differences from Perkins' study. This one analyzed students' average grade scores on individual maneuvers, while Perkins (2003) analyzed overall sortie pass / fail rates of checkrides. This study was limited to T-38 data, while Perkins' study (2003) was based on T-1A student data. This study was limited to students at Laughlin AFB, while Perkins' (2003) included students at both Laughlin AFB and Columbus AFB. In light of Perkins' previous results, it may be of interest to explore whether the current study hypothesis would be supported if the population sample included both T-1A and T-38A students. The T-1A has more automation than the T-38A, so students flowing from the T-6A to the T-1A may exhibit a steeper learning curve over T-37B students. This seems to be indicated by opinion. For example, a former Flying Training Group Commander at Moody remarked that T-6A students transitioning to the T-1A tended to have an easier time going from one glass cockpit to another similarly configured (North, 2003).

Although there seems to be a widespread belief that a primary trainer with a glass cockpit and minimal automation may provide better training for SUPT Phase III than an analog cockpit lacking automation, it is possible that the average student in follow-on training rapidly overcame any disadvantage. To explore this, the researcher performed tests of the earliest Basic and Instrument sorties in the data, but results were the same -- they failed statistical significance. If students lagging in glass cockpit-specific instrument skills caught up with their JPATS-trained peers during the earliest days in the advanced trainer, it would probably be difficult to test. The reason for this is that most of the early sorties are Basic and Contact sorties, which have very little dependence on instrument flight. Students could quite possibly improve their instrument skills and techniques during the composite cross-checks required on those sorties, without totally depending on and being graded for a purely instrument cross-check (i.e., flight without external visual references).

CHAPTER VI

CONCLUSIONS

As stated earlier, the DoD 1989 Trainer Aircraft Masterplan called for replacement of the T-37B before the T-38A in order to base some of the advanced trainer's requirements on the new primary trainer's capabilities (DoD, 1989). With respect to instrument training, the data suggest that the JPATS trainer is no different from the T-37B. This finding may be useful for engineers considering JPATS capabilities during design of the T-38A replacement.

The finding also seems to nullify one assumption of the 2000 USAF ORD which stated that the outdated analog systems of the T-34C and T-37B needed replacement because they did not represent modern aircraft cockpits, and were "limited in training the skills required in follow-on aircraft" (AETC, 2000, p. i). That statement is true at face value, but the data suggest it is irrelevant to student progression. It is obvious the old primary aircraft have become anachronistic and cannot train digital or automation skills. However, the results of this study suggest that T-37 shortcomings do not influence the average student's instrument proficiency in the T-38A advanced trainer.

The new T-6A trainer has been a welcome replacement for its aging predecessor. Former Secretary of the Air Force F. Whitten Peters, who had flown in both the T-37B and T-6A, recently expressed the need for a T-37B replacement: "The T-37's a great airplane, but it had the disadvantage of not having a modern cockpit and modern avionics and modern ejection seats. The T-6 was a much more accurate replica of what pilots will see in the Air Force" (Christenson, 2004, p. 1B). The Secretary's view that the T-6A can provide positive transfer to modern follow-on aircraft is a popular opinion. As previously stated, there is a general belief among AETC IPs that the T-6A is a better overall primary trainer than the T-37B. This study, however, failed to support that opinion.

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APPENDIX A

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APPENDIX B

TABLES

Table 4

T-38A Maneuvers Included in Grade Average Calculations

Maneuver name	Basic MIF ID	Instrument MIF ID
AIRSPEED CONTROL	07	06
ALTITUDE CONTROL	08	07
ARC INTERCEPTION	24	
ASR APPROACH		29
CHANGE OF AIRSPEED		11
CHANGE OF AIRSPEED - STRAIGHT & LEVEL	12	
CHANGE OF AIRSPEED - TURNING	13	
CLIMB	05	
COMPOSITE CROSS-CHECK	33	
CONSTANT AIRSPEED CLIMB / DESCENT	18	
COURSE INTERCEPTION	22	
DEPARTURE	04	04
ENROUTE DESCENT		21
FIX-TO-FIX	26	19
HEADING CONTROL	09	08
HOLDING		20
ILS MANUAL		27
ILS NORMAL		26
INSTRUMENT AILERON ROLL		15
INSTRUMENT CLIMB/DESCENT		12
INSTRUMENT CROSS-CHECK	32	
INTERCEPT/MAINTAIN ARC		17
INTERCEPT/MAINTAIN COURSE		18
LEVEL-OFF	06	05
LOCALIZER APPROACH		28
LOW-ALTITUDE APPROACH		24
MAINTAINING ARC	25	
MAINTAINING COURSE	23	
MISSED APPROACH		34
PAR NORMAL		25
PAR/ASR NO-GYRO		30
RATE CLIMB/DESCENT	19	
SINGLE-ENGINE MISSED APPROACH		35
SINGLE-ENGINE NONPRECISION APPROACH		32
SINGLE-ENGINE PRECISION APPROACH		31
STEEP TURNS		10

Maneuver name	Basic MIF ID	Instrument MIF ID
STEEP TURNS-45 DEG	16	
STEEP TURNS-60 DEG	17	
STRAIGHT-AND-LEVEL	11	
TACAN APPROACH		23
TACAN PENETRATION		22
TURNS	14	09
TURNS TO HEADINGS	15	
UNUSUAL ATTITUDES	20	14
VERTICAL S		13
WINGOVER		16

Note. MIF ID numbers correspond to maneuver numbers listed on Maneuver Item File tables in the T-38A syllabus (see Appendix C).

Table 5

T-38A Sorties Included in Grade Average Calculations

Basic Sorties	Instrument Sorties				
B4201	I4101	I4204	I4303	I5201	I5207
B4401	I4102	I4205	I4304	I5202	I5301
	I4103	I4206	I4305	I5203	I5302
	I4201	I4207	I5101	I5204	
	I4202	I4301	I5102	I5205	
	I4203	I4302	I5103	I5206	

Table 6

Student Grade Averages for Instrument Maneuvers

T-37B students (*n*=35)		T-6A students (*n*=39)	
ID	Grade Avg	ID	Grade Avg
1	4.129277567	12	4.052730697
2	3.767175573	13	3.947663551
3	4.003731343	14	3.838129496
4	3.673913043	15	4.01682243
5	3.790076336	16	3.763500931
6	3.688311688	17	3.85046729
7	4.016853933	18	4.188405797
8	4.075949367	19	4.192015209
9	3.779693487	20	3.850094877
10	3.962686567	21	3.939215686
11	4.030131827	22	3.990548204

T-37B students (*n*=35)		T-6A students (*n*=39)	
ID	Grade Avg	ID	Grade Avg
30	3.683241252	23	3.912568306
32	3.847122302	24	3.702359347
34	3.675233645	25	3.876190476
35	3.842696629	26	3.678571429
36	3.670258621	27	3.84452975
37	3.804100228	28	4.114180479
38	3.923954373	29	3.915224913
39	4.055238095	31	3.741509434
43	3.849775785	33	4.045714286
45	3.923507463	40	4.236641221
48	3.658256881	41	3.853703704
49	3.644736842	42	3.756363636
52	4.034090909	44	4.0
53	3.904135338	46	3.720508167
54	3.577735125	47	3.961397059
57	3.885496183	50	3.695075758
58	4.104364326	51	3.738317757
59	3.868327402	55	3.676573427
61	4.114018692	56	3.743986254
63	4.076208178	60	3.785433071
64	3.793233083	62	4.0
68	3.73308958	65	3.977055449
73	4.17481203	66	4.175
74	3.489932886	67	3.78713969
		69	4.041584158
		70	4.211155378
		71	4.103921569
		72	4.130859375

APPENDIX C

FIGURES

Basic Maneuver Item File					
Man No	*Maneuver*	*Lesson Units / Sorties*			
		B41/2	**B42/1**	**B43/1**	**B44/1**
1	Mission Planning/Briefing/Debriefing		2+	2+	2+
2	Ground Operations	2+	2+	2+	3+
3	Takeoff/Transition to Instruments		2+		3+
4	Departure		2+		3+
5	Climb		2+		3+
6	Level-Off		2+		3+
7	Airspeed Control		2+		3+
8	Altitude Control		2+		3+
9	Heading Control		2+		3+
10	Use of Trim		2+		3+
11	Straight and Level		2+		3+
12	Change of Airspeed, Straight & Level		2+		3+
13	Change of Airspeed, Turning		2+		3+
14	Turns		2+		3+
15	Turns to Heading		2+		3+
16	Steep Turns — 45°		2+		3+
17	Steep Turns — 60°		2+		3+
18	Constant Airspeed Climb / Descent		2+		3+
19	Rate Climb/Descent		2+		3+
20	Unusual Attitudes		2+		3+
21	Slow Flight		2+		3+
22	Course Interception		2		2+
23	Maintaining Course		2		2+
24	Arc Interception		2		2+
25	Maintaining Arc		2		2+
26	Fix-to-Fix		2		2+
27	Descent/Traffic Entry		2+		3+
28	Normal Straight-in		2+		3+
29	Single-Engine Straight-in				2
30	No-flap Straight-in				2
31	Transition to Landing		2		2+
32	Instrument Cross-check		2+		2+
33	Composite Cross-check		2+		3+
34	Inflight Planning/Area Orientation				2+
35	Inflight Checks	2+	2+		3+
36	Front Cockpit Procedures	2+	2+	3+	
37	Trim Failure				2+
38	Communication	2+	2+	2	2+
39	Risk Management/Decision Making		2+	2+	2+
40	Situational Awareness				2+
41	Task Management		2+	2+	2+
42	Emergency Procedures	2+	2+	2+	2+
43	General Knowledge	2+	2+	2+	2+
44	Special Syllabus Requirements		2+		2+

Figure 7. T-38 Basic Maneuver Item File Table. *Note.* From *T-38A Specialized Undergraduate Pilot Training, with changes 1 and 2* (AETC Syllabus P-V4A-A (T-38A) (C2)) (p.29), by the United States Air Force, 2003. San Antonio, TX: Air Education and Training Command.

Instruments Maneuver Item File							
Man No	***Maneuver***	***Lesson Units / Sorties***					
		I41/3	**I42/7**	**I43/5**	**I51/3**	**I52/7**	**I53/2**
1	Mission Planning/Briefing/Debriefing	3+	3+	3+	3+	4+	4+
2	Ground Operations	3+	3+	4+	3+	4+	4+
3	Takeoff/Transition to Instruments	3+	3	4+	2+	4+	4+
4	Departure	3+	3	4+	3+	4+	4+
5	Level-Off	3+	4+	4+	3+	4+	4+
6	Airspeed Control	3+	4+	4+	3+	4+	4+
7	Altitude Control	3+	4+	4+	3+	4+	4+
8	Heading Control	3+	4+	4+	3+	4+	4+
9	Turns	3+	4+	4+	3+	4+	4+
10	Steep Turns	3+	4+	4+	3+	4	4
11	Change of Airspeed	3+	4+	4+	3+	4+	4+
12	Instrument Climb/Descent	3+	4+	4+	3+	4+	4+
13	Vertical S	3+	4+	4+	3+	4	4
14	Unusual Attitudes	3+	4+	4+	3+	4	4
15	Instrument Aileron Roll	2+	3+	3+	3+	3	3
16	Wingover	2+	3+	3+	3+	3	3
17	Intercept/Maintain Arc	2+	3+	4+	3	4+	4
18	Intercept/Maintain Course	2+	3+	4+	3	4+	4
19	Fix-to-Fix	2	3+	4+	2	4+	4
20	Holding	2	3+	4+	2	4+	4
21	Enroute Descent	2	3+	4+	2	4+	4
22	TACAN Penetration	2	3+	4+	2	4+	4
23	TACAN Approach	2+	3+	4+	2	4+	4
24	Low-Altitude Approach	2	3+	4+	2	4+	4
25	PAR Normal	2	3+	4+	2	4	4
26	ILS Normal	2+	3+	4+	2	4+	4
27	ILS Manual	2	3+	4+	2	4+	4
28	Localizer Approach	2	3+	4+	2	4+	4
29	ASR Approach	2	3+	4+	2	4	4
30	PAR/ASR No-Gyro	2	3+	3	2	3	3
31	Single-Engine Precision Approach		2+	3+		3	3
32	Single-Engine Nonprecision Approach		2+	3+		3	3
33	Transition to Landing/Landing	2	3+	4+	1	1	1
34	Missed Approach	2	3+	4+	2	4+	4
35	Single-Engine Missed Approach		2+	3+		3	3
36	Inflight Checks	2+	3+	4+	3+	4+	4+
37	Communication	2+	3+	4+	3+	4+	4+
38	Risk Management/Decision Making	3+	3+	3+	3+	4+	4+
39	Situational Awareness	2+	3+	4+	3+	4+	4+
40	Task Management	3+	3+	3+	3+	4+	4+
41	Emergency Procedures	3+	3+	4+	3+	4+	4+
42	General Knowledge	3+	3+	4+	3+	4+	4+
43							
44							

Figure 8. T-38 Instrument Maneuver Item File Table. *Note.* From *T-38A Specialized Undergraduate Pilot Training, with changes 1 and 2* (AETC Syllabus P-V4A-A (T-38A) (C2)) (p.37), by the United States Air Force, 2003. San Antonio, TX: Air Education and Training Command.